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EXPERIMENTAL STUDIES OF PRESSURE DROP IN COMPACT HEAT EXCHANGER WITH ALUMINUM OXIDE AND MAGNESIUM OXIDE

R. MITHRAN[1] & C. SADHASIVAM[2]

[1]*Student, Saveetha School Engineering, Tamil Nadu, India*

[2]*Assistant Professor (SG), Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, India*

ABSTRACT

A variety of research papers from numerous reputed journals with regard to laminar convective transferred heat has been gathered and analyzed. This article reviews modern studies in a round tube with boundary conditions of CHF for transferred heat by convection, i.e., turbulent and laminar. By adding silver (Ag), nanoparticles of MWCNT or multi-wall carbon nanotubes individually in particular fraction of weight in distilled water as base fluid Agor water and MWCNT/nanofluid of water is obtained and the dispersion of these two nanoparticles simultaneously (Ag: MWCNT::75:25) results in the formation of hybrid nanofluid (Ag-MWCNT)/water. The HRTEM or high-resolution transmission electron microscopy is employed to determine the shape, size and structure of morphology. The images of TEM of the samples of nanoparticles are obtained at dissimilar magnifications. The method or technique of EDX Energy Dispersive X-ray Spectroscopy is particularly used for analysis of element and chemical composition of samples. Based on the principle that a unique atomic structure is possessed by every element, these structures allow a specific set of peaks on its spectrum of electromagnet. The arrangement is authenticated through experimentation of the forced convective coefficient of transferred heat using flow of laminar with boundary conditions of CHF that had been performed using distilled water. The results were associated with a well-known logical solution given by Shah Equation. As a result, the usage of nanofluids displays a rise in transferred heat in conflict with distilled water. The concentration of weight of nanoparticles is responsible for the augmentation of transferred heat and the improvement of transferred heat was observed with the rise in N_{Re}.

KEYWORDS: Experimental Study, Heat Performance Analysis, Chemical Transmission, Nanofluids & Nusselt Number

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Original Article

INTRODUCTION

Heating and cooling of fluid are some of the basic processes employed in industries like chemical, electrical, recovery of heat, cryogenic, fabrication, transportation, manufacturing, A/C, refrigerator and so on. The enhancement in transferred heat along with higher effectiveness is the key requirement for all industries (Elshazly *et al*., 2017; Mojarrad *et al*., 2014). As there is a shortage of resources of energy and the necessity for compact systems, so augmentation methods of transferred heat in a variety of processes are abundant. Another method of improving the co-efficient of transferred heat is an enhancement in the characteristics of thermo-physical properties of the fluid, like conductivity of thermal, viscosity and so on. Fluids like EG or ethylene glycols, water, propylene glycol, oil and so on do not have sufficient capability of transferred heat. This is because of the lower conductivity of the thermal properties of this fluid (Babita and Gupta, 2019; Babita *et al*., 2017). The properties of the thermo-physical properties of the fluid are improved through the suspending metal oxides or metal into the conventional fluid. It is probably due to metal oxide or metal has superior conductivity

of thermal properties when compared with usually employed fluids. This augments the coefficient of transferred heat of the fluid.

A nano-sized particle, i.e., suspended in the fluids of transferred heat is called nanofluids. So, that rid of these restrictions is acquired. This was primarily initiated by (Choi and Eastman, 1995; Mapa and Mazhar, 2005; Ravigururajan, 1998) at Argonne National Laboratory USA. These displayed superior thermal properties like higher conductivity of thermal properties, longer capabilities of time-standing and uniform fluid having a very little obstruction in the flow pipes and channels due to very minute dimensions and a larger area of the surface of the nanoparticles.

A two-step technique and a one-step method are two preparation methods of nanofluids. This demonstrates the classification of preparation methods of nanofluid. The method of two-step is popular for the preparation of nanofluids. The materials like nanoparticles, nanotubes, nanofibers and so on are employed in the method of two-step, which are primarily developed as dry powders. The methods of chemical or thermo-physical properties are employed. In the second step, the powder which is small-sized i.e., nano-sized is dissolved into a fluid. This takes place with the usage of agitation of the force of magnet, mixing of high shear, homogenizing, agitation of ultrasonic and milling of ball (Zhang *et al.* 2010). This demonstrates the representation of the two-step method for preparation of nanofluids.

In the method of one-step, the nanoparticles are prepared and distributed directly in the employed base fluid. The one-step method does not use the processes like drying, storing, transport, and distribution of nanoparticles. This leads to the lowest agglomeration and increased stability. In this process, the particles can be mixed in the traditional fluids with stability.

NEED FOR STUDY

Nanofluids produce valuable distinctive properties in thermal systems. Numerous applications of nanofluids are described in these research works:

- Synthesis of nanoparticles
- Analysis of the behavior of thermo-physical properties of nanofluids, like specific heat, the conductivity of thermal properties, density, viscosity and so on.
- Characterization of nanofluids
- Design and advancement of the investigational system to discover the transferred heat
- Examine the effects on convective transferred heat at dissimilar rates of flowing
- Examination of enhancement of transferred heat with and without the usage of nanofluids.

REVIEW OF LITERATURE

(Mehrali *et al.*, 2015) performed experiments to discover laminar transferred heat and pressure penalty of nanofluids like alumina or water and alumina or water-ethylene glycol in the inlet of a round tube. The nanofluids had more conductivity of thermal properties and viscosity in contrast to base fluids and this is enhanced with enhancing loading of the nanoparticle.

(İlhan and Ertürk, 2017) examined experimentally the transferred heat and dropping of pressure characteristics of Zinc Oxide or EG or Ethylene glycol-water in transient conditions of flow. At 2.5 wt.% of nanofluid, the highest increase in the coefficient of transferred heat was 30% when producing a contrast with base fluid. Results showed some contradictory behavior that at 5 wt.%, there was a decrease in the coefficient of transferred heat.

(Mehrali *et al*., 2015) examined both performing an experimental and arithmetical study to discover an improvement in the transferred heat of nanofluids of GNp underflow of turbulence. Nu, loss of pressure and performance were different in the range of 3-83%, 7.96–25% and 0.4–14.6% for dissimilar concentrations of weight in contrast to the base fluid.

(Hamid *et al*. 2015) experimentally found the transferred heat of TiO2 or water-ethylene glycol. As per the findings, the coefficient of transferred heat improved by improving the NRe. Enhancement obtained in the value of the friction factor was 1.1 times in contrast to base fluid.

(Hussein *et al*., 2017) performed research on transferred heat and characteristics of flow using the hybrid nanofluids comprising of graphene nanoplatelets and MWCNTs or multi-walled carbon nanotubes. The coefficient of transferred heat was observed rising along with the loading of the nanoparticles and decreases along with the rising trend of the NRe. According to the results, SST k-Y model was the best, and it gave the error in mean Nu and factor of friction was 0.44 and 1.82%.

(İlhan and Ertürk, 2017) developed a new type of nanofluid, i.e., hBN or hexagonal boron nitride or water and experimentally investigated forced convection characteristics of transferred heat in a horizontal circular pipe under boundary conditions of CHF. The results showed that improvement of transferred heat of 7%, 10% and 15% for the nanofluid concentration of volume of 0.1%, 0.5% and 1%, respectively. They observed that there is no abnormal change found in the coefficient of transferred heat and also in corresponding Nu. This nanofluid has superior stability and performance, so it could be used in applications of thermal properties of a variety of industries.

(Teng *et al*., 2017) presented a combined experimental and numerical study for Al2O3/water nanofluids to discover transferred heat. The laminar conditions of flow were considered. Results showed that with enhancing the loading of nanoparticle, there was a decrease in wall temperature and Nu enhanced and also obtained increment in pressure drop.

THERMO-PHYSICAL PROPERTIES (NANOFLUIDS)

The different properties of silver (Ag) and MWCNT nanoparticles in water (distilled) were found using empirical formulas y (equations refers literature 5 and 6), respectively. The values were calculated for all weight concentrations. The values of viscosity as well as thermal conductivity for Ag-MWCNT nanofluids were measured using viscometer and thermal conductivity meter, respectively. The properties of Ag, MWCNT and Ag-MWCNT (nanoparticles) and water (distilled) are considered in the present investigation and are presented in Table 1.1. The thermal conductivity, density and viscosity showed increase with the rise in particle concentration, while specific heat showed downward trend with increasing particle loading.

Table 1: Thermo-Physical Properties

Material/Nanoparticles Used	Density (Kg/m3)	Viscosity (mpa.s)	Specific Heat (J/kg K)	Thermal Conductivity (W/m K)
Water (distilled)	1000	0.000798	4187	0.62
Ag	1250	-	240	423
MWCNT	2100	-	702	3000

DESIGN AND DEVELOPMENT OF TEST RIG OF TRANSFERRED HEAT

An experimental structure was designed to perform the experiments of forced convective for the nanofluids. Figure 3 demonstrates the diagrammatic representation of the experimental structure. The experimental test rig is equipped with pumps, heat exchanger, thermocouples and differential transducer of pressure. The test section is made of a horizontal copper tube with 1400 mm length and 8 mm internal diameter approximately. The 1200-mm tube length is heated uniformly with a tape heater (high temperature) with the power of 900 W or higher, which could be varied with the help of variance. The ammeter and voltmeter are employed to measure the power supply. The test section is insulated with thick insulating material to prevent any loss of heat to the surroundings. Ten thermocouples of J-type of 0.1°C accuracy are attached to the outer surface of the tube along the test section at equal length. Two PT-100 thermocouples were also attached at the outlet and inlet of the tube of the test section.

A heat exchanger having 10-12 liters of water used as a cooling fluid for lowering the temperature of the hot fluid coming from the test section.

Here, figure 1 demonstrates the pattern of EDX for Ag, MWCNT and Ag-MWCNT nanoparticles, respectively. Figure 1 represents stronger Ag peaks, which demonstrates the existence of Ag nanoparticles in the sample and Cu peaks in the patterns are because of the copper substrate, which was employed for TEM imaging. Simultaneously, figure 2-4 demonstrates stronger C peaks, which display the existence of carbon nanoparticles in sample and MWCNT particles contain iron (Fe) in small proportion, so Fe peaks are also shown in the pattern and again Cu peaks are a due copper substrate. Again, figure 1 demonstrates the pattern of EDX of Ag and MWCNT mixture; there are peaks of C, Ag, Fe and Cu.

Figure 1: Experimental Structure.

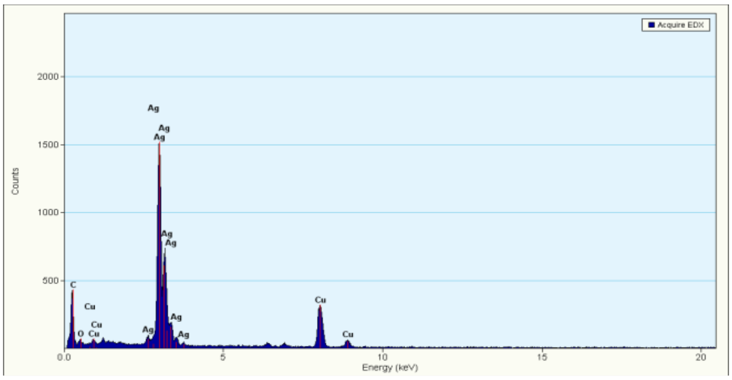

Figure 2: EDX Patterns of Ag Nanoparticles.

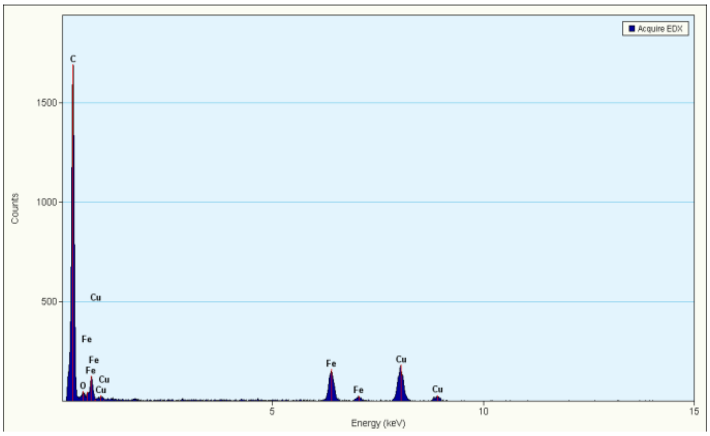

Figure 3: EDX Patterns of MWCNT Nanoparticles.

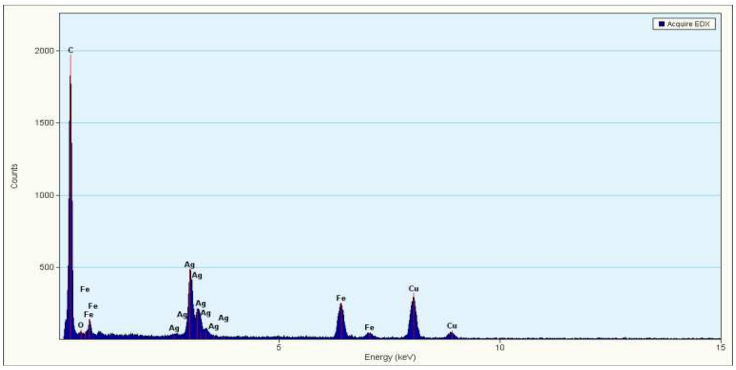

Figure 4: EDX Patterns of Ag-MWCNT Nanoparticles.

RESULTS AND DISCUSSIONS

The enhancement of transferred heat in a thermal system is the main purpose of this research work. The results for fluid flow and transfer of heat in a tube having CHF boundary conditions under the laminar flow regime are presented in this chapter. The three nanofluids like Ag-water, MWCNT-water and nanofluids of Ag-MWCNT-water are employed. The experimentations were achieved with five concentrations of weight like 0.02%, 0.05%, 0.1%, 0.2% and 0.5% of three nanofluids within the Re range, i.e., $1385 < Re < 1985$. The improvement of transferred heat is attributed to the reduction in thermal resistance due to the nanoparticles in the base fluid. Our main quantities of interest are raised in the rate of transferred heat.

Silver/Distilled Water Nanofluids

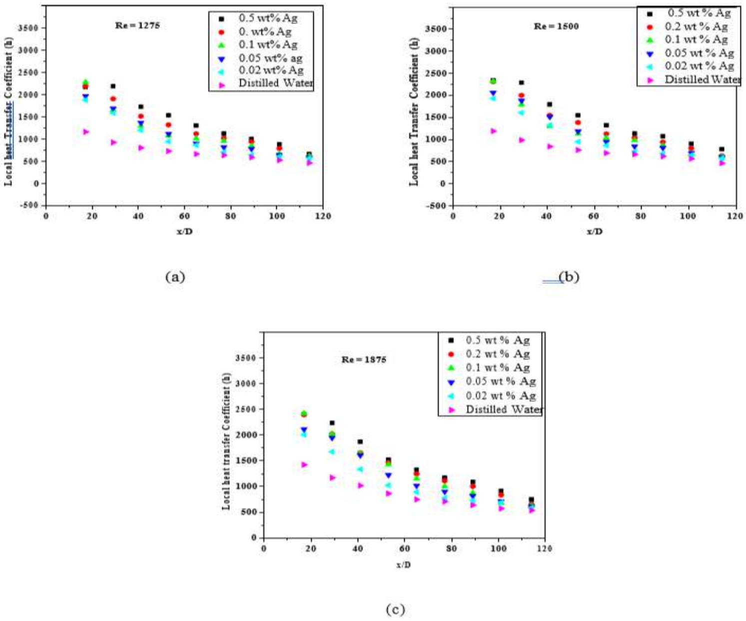

Figure 5: Local Coefficient of Heat Transfer of Ag/Distilled Water along the Axial Length of Test section at Reynolds No. (a) 1385, (b) 1600 and (c) 1985.

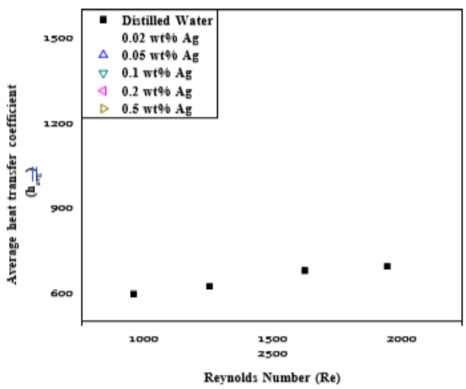

Figure 6: Average Coefficient of Heat Transfer of Ag/Distilled Water (at different Weight Concentrations) with Reynolds Number.

Figure 6(a-c) represents the local coefficient of heat transfer along the axial direction of the tube (CHF boundary condition) for distilled water and nanofluids with particle loadings (0.02 to 0.5) in the Reynolds range (1385 to 1985). The observation shows that the values of local coefficient of heat transfer are maximum at the entry of the section under observation. The coefficient of heat transfer reduced downstream along the length of the section. It can be interpreted; as we go along the axial direction, the thickness of thermal boundary layer raises leading to reduction in the heat transfer. The coefficient of heat transfer for all weight concentrations of nanofluids and Reynolds numbers is higher for Nano fluids in contrast to distilled water figure 8. This can be explained due to rise in thermal conductivity because of dispersed nanoparticles and secondly because of disruption in boundary conditions. The randomness due to Brownian motion also influences the thermal boundary layer (Peng *et al*. 2009)

MWCNT-Distilled Water Nanofluids

Figure 9(a-c) reveals the local convective coefficient of heat transfer along the test tube for distilled water and MWCNT/distilled water having weight fractions (0.02 to 0.5 wt%) at Reynolds number, i.e., 1385, 1600 and 1985 respectively. The trends are similar as in the earlier case. The nanofluids show better results at all weight concentrations and Reynolds numbers that distilled water. Figure 10 depicts the maximum enhancement of 68.6% compared to the distilled water at 0.5 wt% at Reynolds number 1985.

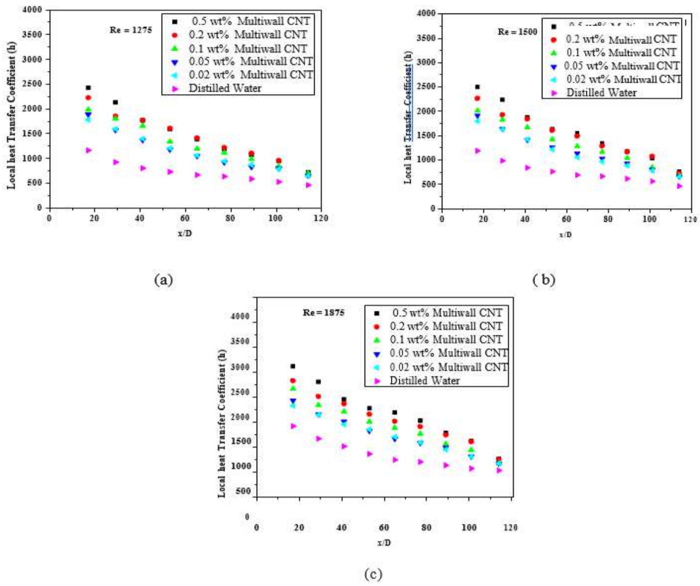

Figure 7: Local Coefficient of Heat Transfer of Multi-wall CNT-Water along the Axial Length of Test section at Reynolds No. (a) 1275, (b) 1500 and (c) 1875.

The nanoparticles of silver and MWCNT were taken together to form hybrid nanofluids in order to have properties of both the nanoparticles. Figure 7(a-c) depicts the variation of convective heat transfer coefficient along the test tube for distilled water and weight fractions (0.02 to 0.5 wt%) of Ag-MWCNT/distilled water nanofluids at Reynolds number, i.e., 1385, 1600 and 1985 respectively. The trends are similar. Figure 8 shows the maximum enhancement of 60.1% compared to distilled water at 0.5 wt% at Reynolds number 1985. The enhancement is in between the above used nanofluids.

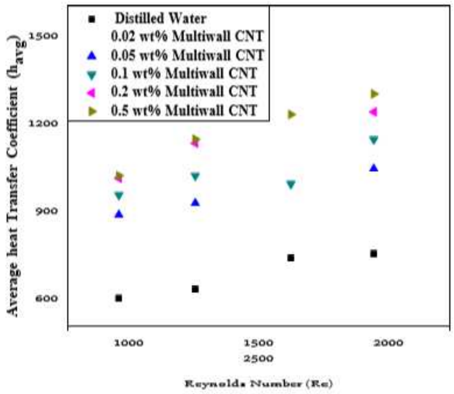

Figure 8: Average Coefficient of Heat Transfer of Multi-wall /Distilled Water (At Different Weight Concentrations) with Reynolds Number.

CONCLUSIONS

The transformation of heat by convection of distilled or silver water, Multi-wall water of distilled or CNT and Ag-Multi-wall water of distilled or CNT of nanofluids having 0.02%, 0.05%, 0.1%, 0.2% and 0.5% concentrations of weight are experimentally examined for laminar flow in and the around tube, i.e., CHF boundary conditions. The NRe was taken between 1385 and 1985. The focal point of the investigation was to evaluate the consequence of the particle weight concentration and NRe on heat transfer characteristics. The observations made from the investigation are as under.

The use of nanofluids reveals a rise in heat transfer in contrast to distilled water. The highest augmentation of transferred heat was observed for MWCNT or nanofluids of distilled water followed by Ag-MWCNT or nanofluids of distilled water and least enhancement was observed with Ag or nanofluids of distilled water for same operating conditions.

The concentration of the weight of nanoparticles is responsible for the augmentation of transferred heat. As the particle loading was increased from 0.02 to 0.5 wt% in 1985, the enhancement was 42.9, 40.5 and 35.9% for Ag, Ag-MWCNT and nanofluids of MWCNT, respectively.

The improvement of transferred heat was observed with the rise in NRe. With NRe rise from 1385 to 1985 at 0.5 wt%, the augmentation 28.8, 20.3 and 21.8% was observed for Ag, Ag-MWCNT and nanofluids of MWCNT, respectively.

REFERENCES

1. *Babita, S. K., and Gupta, S. M. (2019, October 10). [No title]. Retrieved from https://www.researchgate.net/profile/Babita_Sharma13/publication/333057681_Experimental_studies_on_pressure_dropfriction_factor_of_CNT_nanofluids_flowing_through_helical_coils_and_development_of_a_new_empirical_correlation/links/5d42b8c24585153e5932bcde/Experimental-studies-on-pressure-drop-friction-factor-of-CNT-nanofluids-flowing-through-helical-coils-and-development-of-a-new-empirical-correlation.pdf*
2. *Babita et al. (2017). Hydrodynamic studies of CNT nanofluids in helical coil heat exchanger. Mater. Res. Express, 4(12), 124002. https://doi.org/10.1088/2053-1591/aa9bd2*
3. *Choi, S. U. S. and Eastman, J. A. (1995). Enhancing thermal conductivity of fluids with nanoparticles. Retrieved from Argonne National Lab., IL (United States) website: https://www.osti.gov/biblio/196525*
4. *Elshazly et al. (2017). Effect of γ-Al2O3/water nanofluid on the thermal performance of shell and coil heat exchanger with different coil torsions. Heat Mass Transfer., 53(6), 1893–1903. https://doi.org/10.1007/s00231-016-1949-4*
5. *Thakur, G., & Singh, G. (2017). Experimental invistigation of heat transfer characteristics in Al2O3-water based nanofluids operated shell and tube heat exchanger with air bubble injection. International Journal of Mechanical and Production, 7, 263-273.*
6. *Hamid et al. (2015). Effect of temperature on heat transfer coefficient of titanium dioxide in ethylene glycol-based nanofluid. J. Brazil. Soc. Mech. Sci. Eng., 8, 1367–1375. Retrieved from http://jmes.ump.edu.my/images/Volume 8 June 2015/11_Abdul Hamid et al. pdf*
7. *Hussein et al. (2017). A Review of Nanofluid Role to Improve the Performance of the Heat Pipe Solar Collectors. Energy Procedia, 109, 417–424. https://doi.org/10.1016/j.egypro.2017.03.044*
8. *İlhan, B., and Ertürk, H. (2017). Experimental characterization of laminar forced convection of hBN-water nanofluid in circular pipe. Int. J. Heat Mass Transf., 111, 500–507. https://doi.org/10.1016/j.ijheatmasstransfer.2017.03.040*

9. *Mapa, L. B. and Mazhar, S. (2005). Heat transfer in mini- heat exchanger using nanofluids. Conf. American Society for Engineering Education, DeKalb, IL, Apr, pp. 1–2. Retrieved from*

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.492.1686&rep=rep1&type=pdf

10. *Mehrali, et al. (2015). Heat transfer and entropy generation for laminar forced convection flow of graphene nanoplatelets, nanofluids in a horizontal tube. Int. Commun. Heat Mass Transfer, 66, 23–31.*

https://doi.org/10.1016/j.icheatmasstransfer.2015.05.007

11. *Mojarrad et al. (2014). Experimental investigation on heat transfer enhancement of alumina/water and alumina/water–ethylene glycol nanofluids in thermally developing laminar flow. Exp. Therm. Fluid Sci., 53, 111–118.*

https://doi.org/10.1016/j.expthermflusci.2013.11.015

12. *KB, S. S., & DV, S. (2016). Thermal Analysis of Advanced IC Engine Cylinder. International Journal of Automobile Engineering Research and Development (IJAuERD) ISSN (P), 2277–4785.*

13. *Peng et al. (2009). Heat transfer characteristics of refrigerant-based nanofluid flow boiling inside a horizontal smooth tube. Int. J. Refrig., 32(6), 1259–1270. https://doi.org/10.1016/j.ijrefrig.2009.01.025*

14. *Ravigururajan, T. S. (1998). Impact of Channel Geometry on Two-Phase Flow Heat Transfer Characteristics of Refrigerants in Microchannel Heat Exchangers. J. Heat Transfer, 120(2), 485–491. https://doi.org/10.1115/1.2824274*

15. *Teng et al., (2017). Calcium carbonate fouling on double-pipe heat exchanger with different heat exchanging surfaces. Powder Technol., 315, 216–226. https://doi.org/10.1016/j.powtec.2017.03.057*

16. *Zhang et al. (2010). Optimization of Microwave-assisted Extraction Technology of Pectin from Lemon Peel Using Response Surface Methodology [J]. Fine Chem., 1.*

17. *Patel, M. D., Patel, J. H., Rajput, M. B., & Bariya, A. R. (2016). Adaptive physiological and biochemical responses of dairy animals to heat stress: a review. International Journal of Applied and Natural Sciences, 5(1), 107–116.*

AUTHOR'S PROFILE

R.MITHRAN, B.E Mechanical (Bachelor of Engineering in Mechanical) in Saveetha School of Engineering (2019) 6.78 CGPA

ACADEMIC ACTIVITIES:

• Obtained participation at 2015 IYF (International Youth Fellowship) mindset and culture camp.

• Participated in the 2016 2nd ICDAMS (International Conference on Analysis, Manufacturing and Simulation).

• Participated in 2016 “E-WEEK” Organized by Entrepreneurship Development Cell, SSE EDC(Equipped to be Entrepreneurship).

• Participated in 2017 two-day National Level Symposium NUTS & BOLTS.

• Participated in the 2018 3rd ICDAM International Conference on Analysis, Manufacturing and Simulation).

• Completed Course in CATIA conducted by CAD SOLUTION

Sadhasivam. C currently working as Assistant Professor in Saveetha school of Engineering in Saveetha Institute of Medical and Technical Sciences. I am extremely to working as a faculty position at various universities and colleges. I believe that my academic Experience of 11 years and my Five years of experience working as a maintenance Engineer and Pursing doctoral candidate at the Anna University of technology at Chennai and submitted my thesis work. My Ph.D. in Area of Research is Study of Pressure Drop and Friction factor in the Compact Heat Exchanger with Computational Fluid Dynamics and Published 15 papers in international Journals with Scopus indexed.